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CONVEYER-BELT SORTER

A Versatile Electromechanical Sorting System

AN IMPROVED MACHINE for sorting physical objects into a large number of categories has recently been developed by Jacob Rabinow of the National Bureau of Standards. Designed at the request of the Bureau of Census, the device was built to sort punched cards at the rate of 420 per minute. The principle is also applicable to sorting such other objects as mail, electrical and mechanical components, and farm produce, as well as checks, invoices, and other papers. All items that can be separated into a number of subdivisions can be handled by an electromechanical system similar to the NBS sorter.

There are several fundamental approaches to the problem of sorting objects into many classifications. One approach commonly used is to place the objects to be sorted on a conveyer and individually examine them as they pass the various sorting stations. Another method, used particularly in sorting punched cards, is to examine all the cards individually at a single reading station and then to direct them immediately into various tracks. A third method, used in the new NBS sorter, is to examine the objects at one station, feed them into a conveyer, and simultaneously put a mechanical address number into each section of the conveyer belt so that the object and its address number travel together. When the object reaches the correct address, or location, a simple recognition device is excited, and the object is removed from the conveyer.

The first two methods have the disadvantages of being far too cumbersome and expensive, or of being limited to a relatively small number of sortings. The third method, however, will separate items into a large number of categories with only one examining device and comparatively simple terminal equipment.

The machine developed at the Bureau consists of five major components: (1) a sensing unit that reads the data-bearing cards and decides where they should go; (2) an addressing device that loads the conveyer with the cards and their corresponding address numbers; (3) a conveyer belt that carries both the card and its address number; (4) a series of recognition devices, actuated by the information-bearing mechanism of the conveyer belt, which operate trip mechanisms so that the cards are released from the conveyer; and (5) a series of receptacles, or gates to other devices, into which the material borne by the conveyer is sorted.

The NBS machine contains a track on which the cards are pushed by fingers extending down from the conveyer belt directly above. The conveyer belt conveys information in coded form, and the cards are kept in the correct physical location with respect to the address number by the pusher fingers. The conveyer belt is made from two parallel chains whose links are four inches on center and are connected by a crossbar at each card position. Each crossbar carries two nylon wheels on which the chains travel and eight nylon cams that act as the mechanical binary address number.

Each of the cams can be set to one of two positions (corresponding to the binary "zero" or "one") with the

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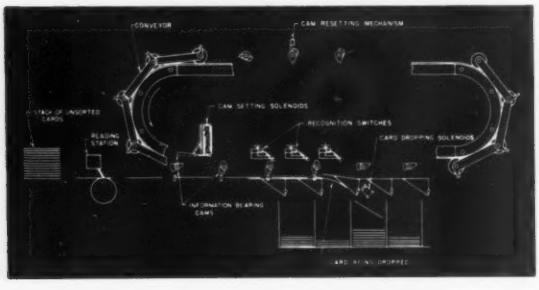
point either down or up. They arrive at the starting end of the conveyer in the clear or "zero" position. If it is necessary to tip the cam upward so that it becomes the equivalent of the binary "one", a pawl is moved into its path. Eight cams, each with two possible positions, provide 2^8 or 256 possible binary addresses. Since in general there are 2^n different addresses possible with n cams, it can be seen that the number of categories into which a quantity of items may be sorted is limited only by the number of cams carried by the crossbars connecting the two chains:

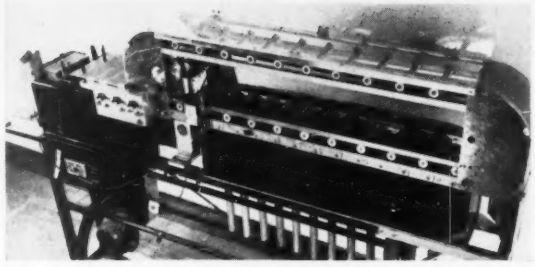
In the sorting operation, the cards are first dealt from the bottom of the stack and pass under a conventional 80-column card reader. When the information on the card is decoded, an electrical device decides into which pocket the card is to go, and the cams are set up with the correct address number. The card is then pushed onto the track. As the cams move down the conveyer with their associated cards, they pass under a series of switches, one set at each pocket. A cam in the upward position will actuate a switch; one in the downward position will not. By properly wiring a set of eight switches, any particular 8-digit binary address number can be recognized, exciting a mechanism that will deflect the card from the track into a pocket.

While conveyer belt sorters of this general type are not new, the NBS machine has several definite advantages. It is not a synchronous machine; that is, the card spacing in the conveyer does not have any relation to the spacing of the pockets. This leads to a saving in the power supply inasmuch as the cards cannot all be dropped simultaneously. However, if the pockets were to have the same spacing as the cards on the conveyer belt, then the cards could be dropped simultaneously although this would not normally occur. Large sections of the belt may be added, as well as groups of pockets in any desired spacing, but the recognizing element in all cases must be spaced a constant distance from its associated pocket. It is also a simple matter to provide more than one pocket for one category; when one pocket fills, subsequent cards can be deposited in a second pocket. Moreover, it is relatively easy to provide a counter associated with each pocket.

If a machine similar to the NBS model were to be designed for sorting mail, it is expected that for some time to come human operators would have to read the addresses on the letters. By means of suitable key-

A schematic diagram shows the recognition switches which are actuated by the cams on the conveyer.





Conveyer belt sorter developed at NBS has 10 pockets. Machines with a much larger number of pockets can be built using the same principles.

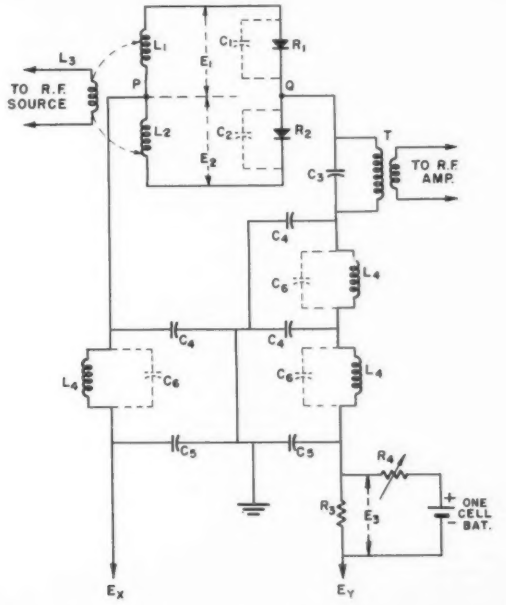
boards, the operators would set up the conveyer belt as the mail is fed into the conveyer. As the speed of the conveyer would normally be much higher than could possibly be matched by one operator, several people would be placed along the belt to feed it. Each operator would set up a series of pawls corresponding to the address on his letter and would then press a transfer key. The conveyer belt cams would be set up, and the letter (or package) would be inserted into the conveyer at the same time. It would be quite simple to provide an additional cam in each set to indicate that a particular space is filled; this would prevent a letter from being transferred until an empty section had arrived at the feeding station.

ERROR VOLTAGE DETECTOR

A BROAD-BAND, low-level error voltage detector has recently been developed by M. L. Kuder of the NBS. Utilizing crystal diodes in a bridge circuit, the device operates on the r-f chopper principle and shows a resolution to 1 millivolt with a bandwidth of at least 1 megacycle. A zero drift stability to 1 millivolt is readily attainable. The instrument answers the need for precise sampling in many servo-control applications.

Some of the most important and rapid technological advances of the past decade have been in the automatic control of machines and processes. Substantial further extension of this trend toward automatization in industrial and military technology seems highly probable. Many significant applications of automatic control are based on servo feedback systems. These systems may be thought of as arrangements in which any deviation of a controlled device or process gives rise to an error signal—usually an electrical voltage. The servo system then initiates a corrective action which continues until the error signal is brought very nearly to zero, that is, until the desired condition is reached.

A crucial element of any servo system is the method or device used for sensing the error signal, which usually means detecting the difference between two voltages. Ideally, a signal detector should be able to measure the error signal immediately when the controlled process deviates from the desired condition by the smallest amount, and to initiate remedial action in the shortest possible time. The need for greater response speeds in some servo applications has brought about a search for a detector which will function more rapidly than a mechanical vibrator or chopper with its limited frequency. The inertia characteristics of a mechanical device place a definite limitation on the overall response speed. The chopper principle, however, must be retained in order that the error detector may respond to d-c signals as well as a-c signals up to video frequencies—a fundamental requirement of many sero applications.



Circuit diagram of the low-level, broad-band, error-voltage detector developed at the Bureau. A feature of this transducer is the use of germanium diodes in a bridge circuit, energized with an r-f source. The r-f chopping signal effects an instantaneous comparison of the two diode resistances. Whenever the diode resistances become instantaneously equal due to the biasing effect of the control signal, a null or minimum r-f output is obtained.

In order to achieve a more rapid sampling rate, NBS found it necessary to eliminate mechanical parts altogether and use electronic circuit elements. Some sensitivity is sacrificed, but the speed of response of the system is tremendously increased. Germanium diodes are used in the critical parts of the detector because best stability is obtained in an electronic circuit by utilizing only passive components. At present, the germanium diode appears to be the best passive chopper element. When it is designed into a device that is self-compensating for temperature coefficients of the crystals, it is capable of unusual zero-drift stability.

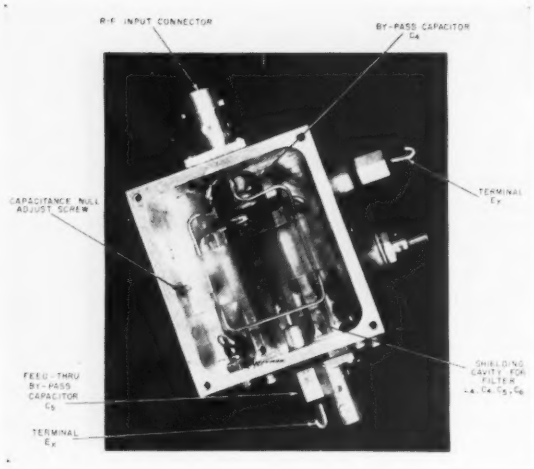
Essentially, the NBS error-voltage detector is a bridge modulator with an r-f carrier as its source and the modulating signal as a dynamic controller of resistive balance. High sensitivity for signals near zero in amplitude is the primary aim, and nonlinear reduction in sensitivity for signals departing from zero is both convenient and desirable. Two of the arms of the bridge are germanium diodes whose forward resistances are compared, and the other two arms are inductors which serve as r-f voltage sources for excitation of the diodes. The usual difficulty with contact potentials in germanium diodes is minimized by having the crystals operate at a high carrier voltage compared to the contact potential.

During one-half of the carrier cycle neither diode conducts and the output is zero. During the other half-cycle the output is still zero when the two diodes have the same forward resistance. But an error voltage applies a differential bias, unbalances these resistances, and causes a portion of the r-f carrier to appear at the output. Thus the error voltage causes partial half-wave rectification of the r-f source, and this output voltage itself contains a component at the r-f frequency which is amplified and serves as the indication of the error-signal voltage.

Mechanical details are important in the design and construction of the detector. Excellent shielding between input and output circuits is essential, since a small leak from the r-f source will greatly reduce the sensitivity. Adequate shielding is provided by milling the main body of the transducer from a block of aluminum. A solid partition between the milled-out cavities reduces r-f leakage to a minimum, and thick walls furnish a heat sink for the two germanium diodes. The filters used in the circuit are well protected from stray fields of the bridge circuit; this makes it possible to achieve an unusually good null balance and thus insures high sensitivity.

The transducer is not limited to a 30-megacycle carrier frequency. The general principle is readily adaptable to the use of an ultra-high-frequency carrier and will extend the bandwidth of the instrument if desired. If less bandwidth is required, a lower-frequency signal may be utilized with consequent economy of construction.

The use of an r-f carrier in combination with the transducer containing only passive elements makes multichannel operation unusually attractive because of its complete freedom from switching transients. One possible practical scheme involves a rotating r-f link coupling a number of transducers to a single amplifier. All moving contacts are avoided, and it is merely necessary to sample synchronously the amplifier output coincident with the positioning of the link. Moreover, this method of multichannel sampling permits the



Interior construction details of the NBS error-voltage detector. The body is milled from a solid block of aluminum.

transducer units to be placed near the sources of the signals to be amplified. It is quite practical to provide coaxial cable connections from the numerous units to a common point where the r-f commutation into the amplifier is accomplished.

The flexibility, accuracy, and reliability which the NBS instrument provides should make it suitable for many applications in nucleonics and other processing plant operations where precise automatic controls are needed.

For further technical details, see A broad-band, low level, error-voltage detecter, *by M. L. Kuder. This is scheduled to appear in an early issue of Review of Scientific Instruments.*

Studies of

THE MOONEY VISCOMETER

RECENT INVESTIGATIONS at the Bureau have led to a better understanding of the utility and limitations of the Mooney viscometer—an instrument widely used for quality control in synthetic rubber production and in rubber processing. In the course of these studies, which were sponsored by the Reconstruction Finance Corporation, G. E. Decker and F. L. Roth of the NBS rubber laboratory have developed designs for the viscometer rotor and dies which provide improved dimensional stability, better heat-transfer characteristics, and much greater uniformity of results. Rotors and dies constructed to the Bureau's specifications have been placed on trial in synthetic rubber plants and by rubber manufacturers with a view toward their eventual standardization.

The Mooney viscometer, invented in 1933 by Melvin Mooney of the United States Rubber Company, consists of a disk rotating in a shallow cylindrical cavity filled with the rubber under test. The rubber is squeezed into the cavity under considerable pressure. The surfaces of the disk, or rotor, and of the dies which form the cavity are serrated in a grid pattern to grip the rubber mechanically. The force required to rotate the rotor at a constant rate—ordinarily 2 rpm—is measured by deflection of a calibrated spring and is proportional to the mean viscosity of the rubber in arbitrary units. The viscosity is obtained at an elevated temperature, generally 212° F., the instrument being heated either by steam or electricity.

When the Government's synthetic rubber program started in 1942, the Mooney viscometer had not been standardized sufficiently to become a practical tool for the rubber industry; results with a given instrument were not reproducible, and serious disagreements were found in results obtained in different laboratories. The Office of the Rubber Director therefore requested the Bureau to develop a standard procedure of operation, to standardize the dimensions of the parts, and to improve the design of the viscometer. Intensive studies resulted in the standard NBS model of the Mooney viscometer, which has been useful for quality control and for measuring the properties of natural and synthetic rubbers. Also, during the past decade, the Bureau has developed standard procedures for measuring viscosities of synthetic rubber, devices for automatic recording, a mechanism for measuring recovery, means for better control and measurement of temperature, and procedures for adjustment and calibration. Much has also been learned concerning the rheology of rubber, which exhibits viscous as well as elastic behaviour.

More recently, problems arose as a result of the commercial production of synthetic rubbers having higher molecular weight. Also, several plants reported that different commercial rotors yielded different viscosities for the same rubber. At the request of the Office of Synthetic Rubber of the Reconstruction Finance Corporation, NBS undertook an investigation of these difficulties and studied the influence of variations in rotors, dies, and rate of shear on Mooney viscosity.

Two Mooney viscometers were used in the investigation. Mooney viscosities, or viscometer readings, for both machines were automatically recorded on charts. A d-c motor and an electronic control were used in combination with mechanical speed reducers to obtain various rotor speeds. Several rotors having different thicknesses and having serrations of different depths

were employed. The dies were of hardened tool steel. One set of dies was supplied commercially and had serrations about 0.015 inch deep. The other set had no serrations and was designed so that the die and die holder were made from a single piece of metal. The depth of the specimen cavity formed by the smooth dies was made slightly greater than that formed by the commercial dies in order to obtain equivalent viscosity readings. Viscosities of several rubbers and rubber compounds were measured with each of the rotors and with each of the two sets of dies.

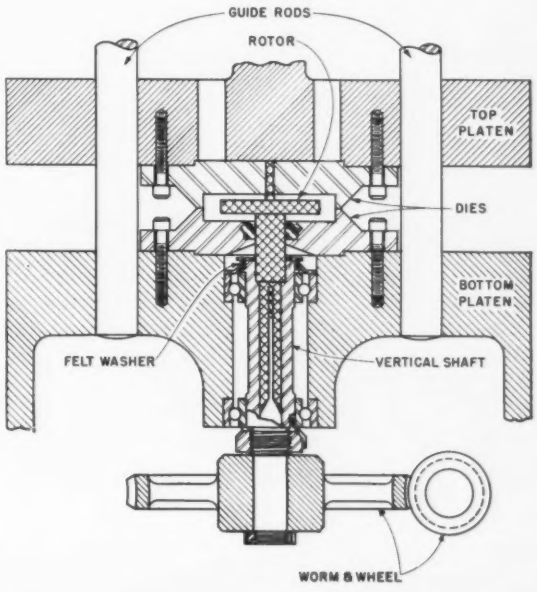
Although the commercial rotors did not meet the dimensional tolerances specified for eccentricity and perpendicularity of the rotor head to its axis, these variations were not responsible for the differences noted in the results. Instead, it was found that variations in the serrations, for which there were no tolerances, had a pronounced influence. Two reasons for this were apparent. First, the serrated design permits rubber to slip or shear along the portions of the grooves which are in line with the direction of motion. Second, the pinnacles at the edges of the rotor are easily broken, resulting in a change in rotor dimensions. These observations led to a study of smooth rotors and dies.

For most commercial rubbers, the smooth parts were found to be satisfactory. However, recently produced rubbers having higher molecular weights slipped more on the smooth than on the serrated surfaces. It was found that slippage of these higher-molecular-weight rubbers depended not only on the mechanical nature of the surface but also on the chemical nature of the surface and the speed of the rotor. Slippage was greatest on cadmium- or chromium-plated surfaces and least on surfaces coated with gold, silver, or a metallic sulfide.

On the basis of these observations, steel rotors and dies were designed in which the usual serrations were replaced by radial V-grooves. A layer of iron sulfide which formed on the surfaces during initial tests of rubber compounds reduced the tendency to slippage. In this type of design the depth of the grooves is not critical because the grooves are always perpendicular to the direction of motion and the rubber cannot slip or shear along them. The dimensions of the rotor are also more stable because there are no small pinnacles at the edge which can break off or wear rapidly. The relatively large smooth areas and V-grooves contribute to greater ease in removing the sample and cleaning the metal surfaces. In addition, the V-grooves permit the die and die holder to be fabricated as an integral unit. This integral design increases the rate of transfer of heat from the apparatus to the rubber so that steady state conditions are reached sooner.

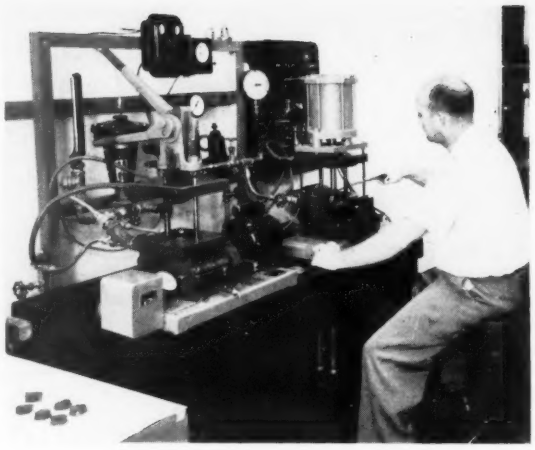
The improved design also includes a thermocouple well in the die for use in measuring its temperature. Studies conducted by Decker and R. D. Stiehler, also of NBS, indicate that the customary methods of measuring temperature, either by mercury-glass thermometers in the platens used to press the dies together or by a thermocouple inserted through a metal tube in the rubber, are not reliable. Although a knowledge of the rubber temperature is particularly important in the determination of vulcanization characteristics, there is no practical means of measuring it directly. The best alternative is to measure the temperature of the dies which form the cavity enclosing the rubber.

In the case of rubbers having very high molecular weights, slippage in the viscometer could not be prevented by any known mechanical or chemical means under the standard method of operation. For many of these rubbers, it was found that slippage could be avoided by reducing the speed of rotation of the rotor. However, at very low speeds the accuracy of measurement is impaired because the torque on the rotor is so small that it is comparable with the frictional forces in the viscometer. Also, the time involved in determining the viscosity becomes too great for control testing. NBS studies showed that at a rotor speed of 0.1 rpm the time required to obtain a reliable reading is not excessive and the frictional forces are still small compared to the torque on the rotor. The practical usefulness of the Mooney viscometer is thus limited to rubbers that do not slip at 0.1 rpm. Results for rubbers of extremely high molecular weight, requiring even slower rotation of the rotor to prevent slippage, must be interpreted with caution.



Improved NBS model of the Mooney viscometer. Closure of die cavity forces rubber to surround the rotor and completely fill the cavity. With the specimen thus held under pressure, the rotor is driven at a constant speed, and the torque required to shear the rubber between the surfaces of the rotor and the die cavity is measured by the deflection of a calibrated spring. The reading of this deflection at any instant is taken as the Mooney viscosity.

Two steam-heated models of the Mooney viscometer were employed by NBS in its study of effect of variations in rotors, die surfaces, and rate of shear on operation of the instrument. Data were recorded automatically. Rubber specimens for test are visible in the left foreground.



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Determination of Aldehyde in Glucose*

CURRENT STUDIES at NBS suggest a promising method of attack in chemical investigations of the degradation of cellulose. Procedures using acid sodium chlorite for the quantitative determination of aldehyde groups in glucose—one of the principal building blocks in the cellulose molecule—have been developed by H. F. Launer,[1] W. K. Wilson, and J. H. Flynn of the Bureau staff. The presence of increasing amounts of aldehyde groups in carbohydrate polymers is related to molecular degradation.

Cellulose in wood, paper, textiles, and other common materials is a high polymer built up from carbohydrate monomer units, chiefly glucose. Other aldose sugars—such as xylose, arabinose, and galactose—as well as modified sugar units, may also exist in cellulose. Aldose sugars, as suggested by the name, contain an aldehyde group. In carbohydrate polymers, such as cellulose, this aldehyde group is initially tied up in the molecular chain with the exception of the unit at one end of the chain. But when the polymeric molecule has been modified by action of light, heat, or chemical reagents, it may contain other free aldehyde groups in addition to that which occurs at the end of the chain. Methods for determination of aldehyde in aldose sugars are thus of considerable importance for research into mechanisms of cellulose deterioration.

Commonly accepted methods for the determination of aldehyde in cellulose employ an alkaline medium. Although alkaline methods are often useful, some modified celluloses are quite sensitive to alkali and may be hydrolized or otherwise degraded by it. This results in an ambiguous result for aldehyde content. Acid solutions of sodium chlorite, on the other hand, do not attack functional groups in cellulose or sugars with the exception of the aldehyde group, which is quantitatively oxidized to carboxyl. This fact suggested that aldehyde in cellulose could be determined by means of oxidation with acid chlorite. In connection with a general program on the degradation of cellulose, NBS has therefore undertaken an investigation of the quantitative oxidation of aldose sugars by means of acid solutions of sodium chlorite.

A difficulty with the sodium chlorite method is that solutions of chlorite salts are unstable in acid medium. As chlorite reacts rather slowly with aldehyde in hexose sugars, appreciable decomposition of chlorite occurs during the reaction. In preliminary work with hexose sugars, particularly glucose, this difficulty has been overcome in two ways: (1) by use of a calibration curve relating chlorite consumed to aldose oxidized for specific experimental conditions, and (2) by the development of an analytical expression from kinetic and stoichiometric considerations. The former procedure is more accurate, but the analytical expression is more flexible, as it applies over a range of experimental conditions. However, either procedure gives experimental values for glucose within a few percent of the theoretical value, the accuracy depending on the amount of glucose present.

The kinetics of the oxidation of glucose have been studied over the experimental ranges of 3.4 to 4.4 pH, 30° to 65° C., 0.005 to 0.15 molar sodium chlorite, and 0.00006 to 0.0016 molar glucose. The reactions were

[1] *Now at Western Regional Research Laboratory, U. S. D. A., Albany, Calif.*

For further technical details, see* Determination of glucose by means of sodium chlorite, *by Herbert F. Launer, William K. Wilson, and Joseph H. Flynn, J. Research NBS, Vol.* **51, *No. 5 (November 1953).*

followed by determining the change in chlorite concentration, as shown by iodometric titration and by photometric measurement of the soluble yellow gas, chlorine dioxide, formed in the oxidation of aldose by chlorite. Cellobiose, melibiose, maltose, and lactose were all oxidized at about the same rate as glucose, but nonreducing sugars and sugar acids were not appreciably oxidized under the conditions of the experiments.

Precise Determination of Orthophosphate

UNTIL NOW the precise determination of phosphate in rocks, bones, teeth, fertilizer, and other materials has been a difficult and time-consuming process because both gravimetric and volumetric methods require the complete separation of calcium and other interfering elements. The more rapid colorimetric procedures, while adequate for most routine purposes, do not have the precision that is often required. Recently, Drs. Allen Gee and V. R. Deitz at the National Bureau of Standards, developed a rapid one-step procedure for orthophosphate determination which combines the essential simplicity of a spectrophotometric method with the precision of careful gravimetric analysis. Their work was done in connection with a research program sponsored at NBS by the Sugar Research Foundation, Inc.

The proposed method uses the techniques of differential spectrophotometry, but some refinements have been introduced. The method is based on the yellow complex (molybdivanadophosphate) formed when phosphate reacts with a mixture of molybdic and vanadic acids. Solutions of the yellow complex are made up to high absorbency (less than 1 percent transmission) in the near ultraviolet, and their absorbency is compared with that of solutions containing known amounts of phosphate. While the absorbency of the yellow solutions changes measurably with standing, this source of error is eliminated by comparing solutions developed simultaneously.

The procedure employs the Beckman DU Spectrophotometer with an incandescent lamp, a wavelength setting at 390 millimicrons, and a slit opening of about 1 millimeter. The selection of this wavelength permits the use of the glass filter supplied with the instrument to take out the stray light of wavelengths above 400 mμ, which must be completely eliminated.

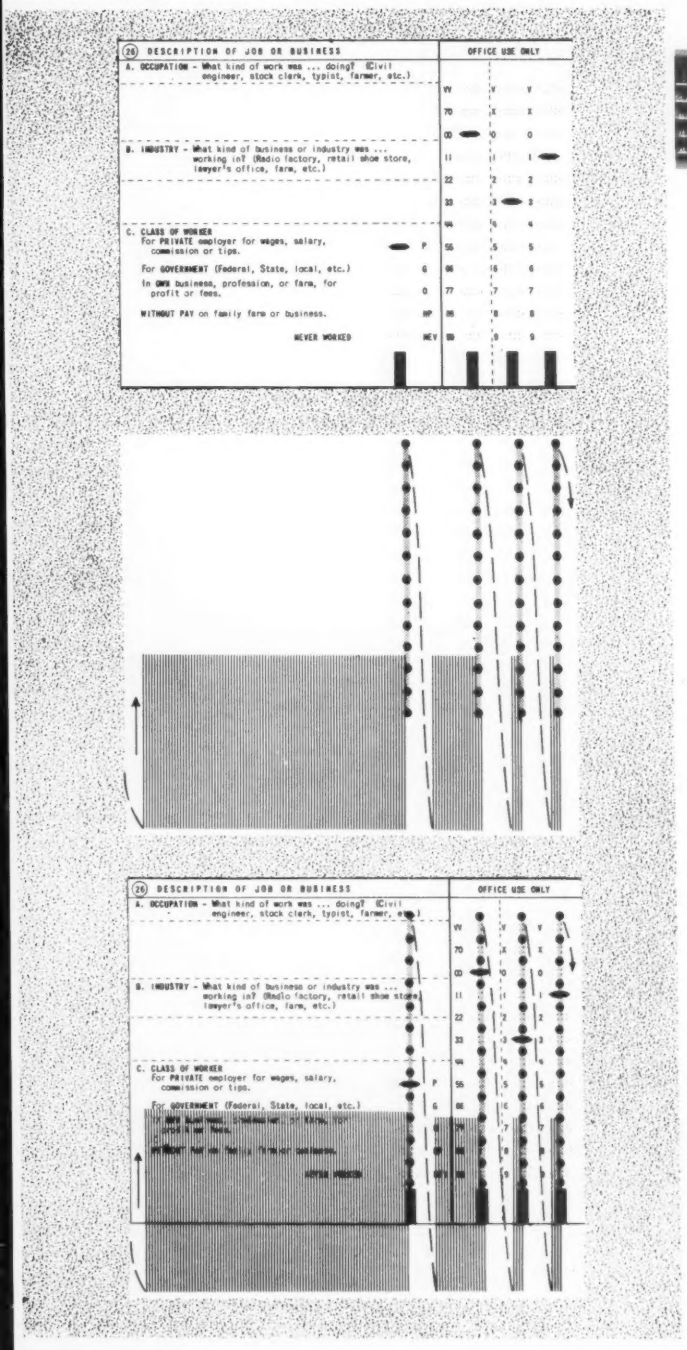
In practice, aqueous solutions of ammonium molybdate and ammonium metavanadate, as well as a standard phosphate solution containing perchloric acid, are prepared in advance and kept on hand. When a phosphate determination is to be made, the unknown material, ordinarily dissolved in hydrochloric acid, is diluted with water. Aliquots of this solution are taken which contain amounts of phosphate varying over a small range—say, 4.5 to 5.5 milligrams of P_2O_5 per 100 milliliters of final volume. At the same time the standard phosphate solution is used to make up two or three standard solutions covering this range. A solution containing the appropriate amounts of ammonium molybdate, ammonium vanadate, and perchloric acid is then added quickly to each flask which holds the unknown or standard solution, and the remaining volume is made up with water. A 1-cm absorption cell is filled with the lightest-colored solution, and all the other solutions are successively placed in a second cell and compared spectrophotometrically with the first solution. The phosphate content of the unknown solutions is interpolated from the absorbancies and known phosphate contents of the standards. A linear extrapolation for measurements not bracketed by the standards can be made, though with somewhat reduced precision.

Under optimum conditions phosphate concentrations can be compared by this method with a precision of 1 part in 3,000. Results are thus comparable with the best gravimetric procedures. With proper dehydration of silica, NBS standard phosphate rocks can be analyzed to an accuracy of 1 part in 1,000. Since few substances (notably silicate and arsenate) interfere appreciably with the absorbency measurement, the procedure should have rather wide application. NBS experiments indicate the possibility of adapting the process to various types of analyses.

For further details see Determination of phosphate by differential spectrophotometry, *by Allen Gee and Victor R. Deitz, Anal. Chem.* **25**, *1320 (1953).*

A spectrophotometer is being used to determine the phosphate content of a standard rock sample by comparing the optical absorbancy of solutions of a yellow complex prepared from the sample with the absorbancy of standard solutions. Phosphate content of the unknown solutions is interpolated from the absorbancies and known phosphate contents of the standards.

FOSDIC—A Film Optical Sens



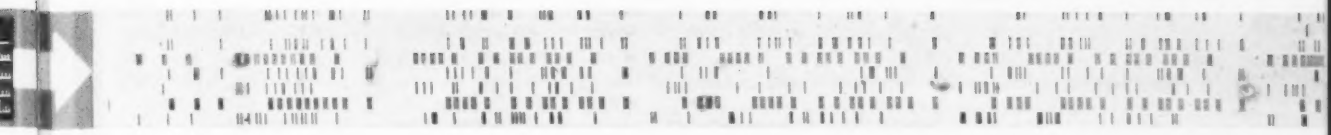
a data reader capable up to 10 million answe hour for use in electr

AN INSTRUMENT that provides rapid, automatic processing of information into a form suitable for direct input to large-scale electronic computers has been developed by M. L. Greenough, H. D. Cook, M. Martens and associates of the National Bureau of Standards at the request of the Bureau of the Census. Named FOSDIC (Film Optical Sensing Device for Input to Computers), the machine reads marks on microfilmed copies of documents that have been marked with an ordinary pencil or pen, and then processes the information into electrical pulses which are recorded on magnetic tape for direct input to an electronic computer such as the Census Univac. FOSDIC is designed to reduce the work that is now involved in converting written records into a medium acceptable as input by data-processing machines. This is particularly true since FOSDIC allows considerable freedom in design of the documents and does not require the use of any special writing instrument.

It is anticipated that ultimately the use of this machine will reduce appreciably the massive amount of paper-work entailed in summarizing Census information on the entire population. Although designed for census operations, FOSDIC may be generally applied to the processing of other types of information that must be handled in large quantities.

Top: **Portion of a census document designed to be read by FOSDIC. Large black marks at the bottom of each column of ovals are index bars used to locate the columns.** ***Center:*** **Scanning pattern. Vertical excursions to read answer marks are caused by recognition of index bars.** ***Bottom:*** **Scanning pattern superimposed on census document. It is scanned rapidly over a large area to locate the first index bar. When index is found, the ovals in the column are searched for answer marks. Black dots indicate where the beam stops between ovals to allow readout on tape. When the column is completely read, the beam searches for the next index and then reads its associated column of ovals. The process continues until the entire document is read; then the microfilm is advanced to a new frame and process is repeated.**

ensing Device For Input To Computers



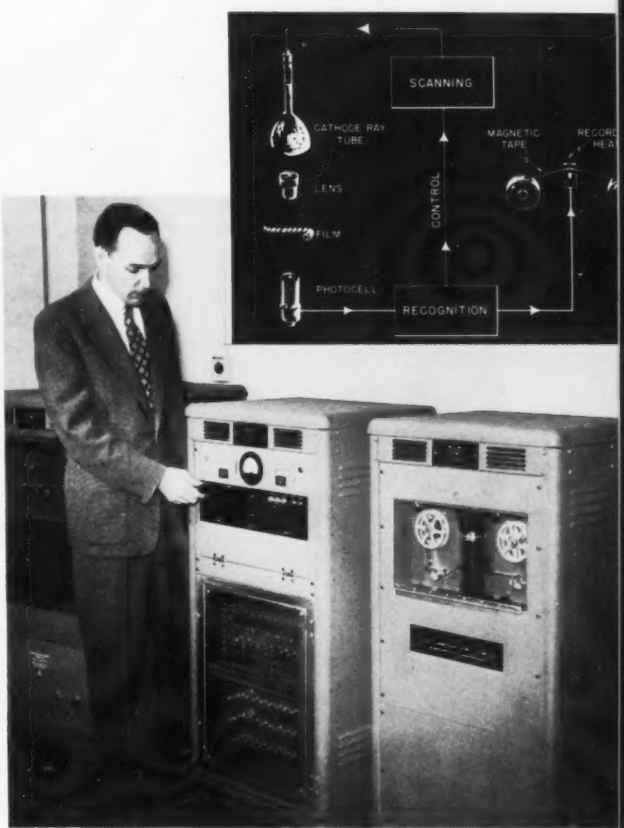
capable of translating n nswer positions per n lectronic computers

With the development of many large-scale electronic computers in the past few years, there has been an increasing need for equipment to bridge the gap between the machines and their sources of information. This is especially true for computing systems which perform relatively little computation on a large mass of data obtained from many sources. Considerable attention has been given to computers and their input-output equipment but relatively little to "pre-input" apparatus or instrumentation permitting the computer to have direct contact with sources of informaion. When human beings are considered as sources of information, only two partially automatic means of communication are in general use. These are (1) typewriters of various forms and (2) special marking instruments such as punches or conductive pencils. An alternate method is through the manual preparation of punched cards. To these methods has now been added FOSDIC, a completely automatic machine which processes marks made by an ordinary pencil or pen into a form directly usable by the computer.

The method of mark sensing used by FOSDIC is the detection of specific blacked-in areas or ovals in a large field of possible answers arranged on a sheet of paper. A "yes-no" answer is given two ovals while a numerical answer is supplied with a vertical column of 10 ovals for each decade. The desired information is indicated by the locations of the marks. It then becomes the task of the sensing equipment to tell the computer precisely which ovals the enumerator has marked to signify his available information. Since FOSDIC senses the presence or absence of a mark by optical means, readings are not affected by the electrical conductivity of the mark or the paper, or by any mechanical indentation of the paper due to lack of stiffness.

The scanning process is carried out on a frame-by-frame basis. Each frame is a microfilmed picture of one side of a sheet which may be as large as 14 by 16 inches. The film is placed in an optical assembly between a cathode-ray tube with a moving spot that scans

Above: **Information on microfilm is translated into pulses and recorded on magnetic tape.** ***Below:*** **At right is the cabinet containing the cathode-ray scanning equipment that reads microfilmed copies of marked documents. In the center is the main electronic unit which generates the scanning voltages and receives the photocell signals. Answer information is fed into the output unit at the left where it is converted into coded-pulse form.**



the image and a photocell that produces a varying electrical signal from the light beam that has passed through the film. The current maximum capacity is about 2,800 marks per sheet, since this is the present limit of adequate legibility of marks on the document. An individual frame is scanned in 0.5 to 0.9 seconds. Allowing for film change and other functions, the total time per frame is about 1¼ seconds. The average information rate is approximately 2,000 binary digits or 250 decimal digits per second.

The chief problem in the design of mark sensing equipment lies in developing a method for locating the individual ovals with the necessary degree of precision. In a mechanically registered system, such as that used for detecting conducting-pencil marks, the pickup heads are located at fixed distances from the edge of the document. The assumptions are made that the edges are well-defined and that the paper stock has dimensional stability. In FOSDIC, however, the paper edge is replaced by a printed index mark below each column. When located by the scanning process, the index mark furnishes an exact guide to the column position. Column height, or distance from top to bottom oval, is not as critical as in a mechanical system since each answer is searched for over an area several times the size of the oval. Thus, with these degrees of freedom over ordinary scanning methods, the use of multiline documents on ordinary bond paper stock is feasible. The amount of information per document is considerably increased over punched cards.

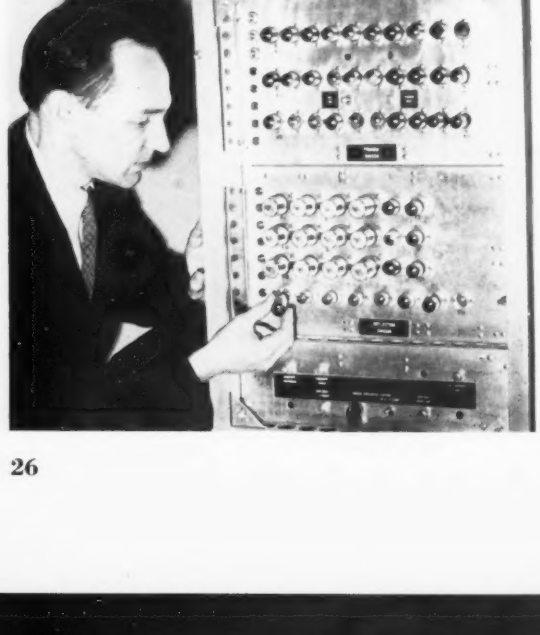
The NBS-developed instrument is housed in four 42-inch high cabinets. In addition, there is a unit containing magnetic tape handling equipment and recording heads. The input cabinet contains the flying-spot scanning assembly. The main electronic unit generates scanning voltages which drive the cathode-ray tube beam, and receives in return the photocell signals from the scanning assembly. Answer information is fed into the output cabinet where it is converted into coded-pulse form suitable for recording on 8-channel magnetic tape. Power is supplied to all these units from the fourth cabinet.

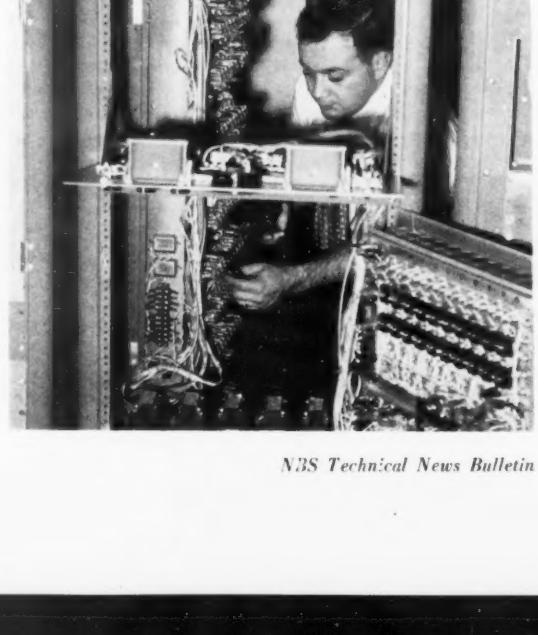
FOSDIC's electronic equipment is composed of many separate and distinct circuit groups, each designed to carry out a unique function. For example, the Index Recognition circuit determines when the scanning beam is at the top edge of a solid mark between 0.24 and 0.36 inches high. To make this decision, however, it must previously have been informed that a number of other conditions have been met. Among these conditions are : (1) a frame to be scanned must be present, (2) the degree of tilt of the document must have been measured, (3) the scanning beam must be over the page, and (4) the apparent index mark must be genuine and not a thin vertical line crossed obliquely by the scanning beam. The reading program begins immediately after recognition of the index mark occurs.

All information is read out in serial order in blocks of 720 characters and occupies four of the eight channels on the magnetic tape. A character consists of four digits; thus each block can contain more than 2,800 digits. Each document, either single or double sided, is included in one block and the remainder of the 720 characters is made up of dummy pulses. To assure that the order is not upset by the loss of a column somewhere on the page, FOSDIC makes a column count on each document. If a column is missed for any reason, such as a film defect, a characteristic record is made on the tape informing the computer that information in this block is not trustworthy. Information contained on such documents is then restored to the tape by a supplementary correction process.

Although a complete check is maintained on the information so that it cannot get out of order, this check

A majority of FOSDIC's components were mounted on the cabinet doors making maintenance easy. *Left:* Back door of cathode-ray scanner. *Right:* Unit which generates scanning voltages and receives photocell signals.





is not as thorough nor as elaborate as a check on individual answers. Determination of overall system reliability was left to special evaluation tests in conjunction with the Univac computer. The instrument itself shows near-perfect response when operated under good marking and filming conditions. Tests with the Census computer indicate that film defects are the largest source of the few mistakes. For example, holes in the emulsion which happen to lie at an answer area leave FOSDIC with no choice but to declare an apparent mark. Although adequate statistics on the probability of these errors are not yet established, preliminary results for standard commercial processing appear to show less than one error in 100,000 ovals. If further tests indicate probable errors as infrequent as this, then it can be concluded that the transcription process through FOSDIC, including filming, does not appreciably add to other sources of error in the enumeration process.

Using electronic scanning, a high degree of flexibility can be incorporated into the instrument to meet or ameliorate practical operating conditions. It offers advantages to almost all of the activities involved in the information collection process. Greater freedom in document layout and choice of size, lower cost of document paper stock, more tolerance to the weight and positioning of answer marks, and a large reduction in handling care are all obtained through the electronic scanning provided in FOSDIC. Among the more significant benefits are the use of multiline documents several times the size of standard typewriter sheets but no thicker or stiffer, detection of rapidly made single-stroke marks of reasonable boldness, and tolerance to an appreciable amount of document mutilation and misalignment during handling and processing.

In many Census operations, microfilming has already been carried out as a routine procedure. The special problems thus introduced are the additional time for processing, the exposure control that is required, and errors due to the presence of dust and imperfections on the film. However, the use of the intermediate memory in the form of microfilm offers a number of advantages which well outweigh the problems it creates. For example, the massive paper-handling operation is separated from the scanning equipment, the mark strength is increased through the use of high-contrast films, and the electrical signal-to-noise ratio is enhanced.

printed circuit techniques

A Miniature Electrostatic Generator

A MINIATURE ELECTROSTATIC source of high voltage for use with radiation survey instruments has been developed by S. R. Gilford, S. Saito, and J. L. Herson of NBS. The device is an adaptation of the work of Holtz and Wommelsdorf [1] on influence-type generators of conventional size, but it uses modern printed-circuit and miniaturization techniques. Operation of this type of generator depends on the ability of one charged body to induce a charge on another body close by. The device is one result of a program sponsored by the Navy Bureau of Ships for the investigation and application of techniques adaptable to low-cost mass production of radiation survey instruments.

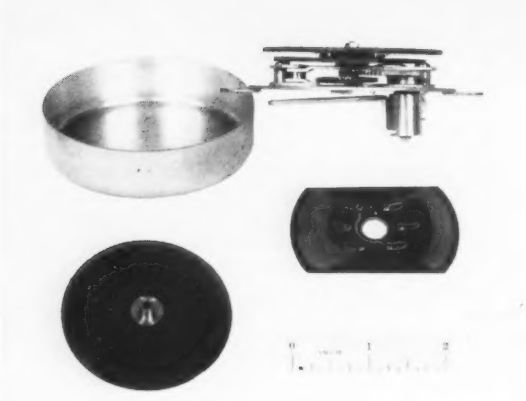
Many instruments for the detection and measurement of nuclear radiation require high-voltage sources of low current to supply polarization potentials for ionization chambers. Conventionally, this voltage is obtained from miniature high-voltage batteries used directly or in combination with capacitors charged in parallel and then connected in series, from a vacuum-tube oscillator in combination with a high-ratio transformer and rectifier, or from a vibrator power supply. The NBS generator was designed to replace these sources. It is simpler to fabricate and potentially less expensive, has fewer components, and avoids the use of special batteries that may be difficult to obtain.

The alpha survey meter using the air proportional counter provides an opportunity for application of this electrostatic source. The probe requires 2000 volts at a current of 10^{-12} to 10^{-14} ampere, which can be obtained conveniently from a storage capacitor recharged periodically by the new generator.

The generator consists basically of a stator of two field plate conductors, and a rotor with a number of pairs of conducting sectors. Printed circuit techniques are used to apply the conducting areas to the flat insulating plates of the rotor and stator. Several sets of brushes transfer electrical charge between the components of the system and the storage capacitor. The attached driving system enables the rotor to be driven at speeds as high as 6,000 rpm by a reciprocating drive mechanism operated by an external lever. Although simpler drive systems were devised, the reciprocating type was chosen for its convenience, small size, and the ease with which it can be adapted to a hermetically sealed generator.

One problem in the development of the NBS generator was devising a method for establishing a unique polarity of output voltage. The randomness of the initial charge distribution which determines the output polarity can be overcome in several ways. One method relies on the use of a dielectric material which retains charge for a long period of time. Another scheme utilizes the triboelectric potential of different brush materials and dielectrics to establish the initial charge distribution. A third method, used in the NBS instrument, requires the use of a small external bias voltage to precharge the generator. The biasing method was

[1] *U. S. patent no. 1,071,196. August 26, 1913.*



Top: **The assembled NBS miniature electrostatic generator with its reciprocating drive mechanism.** ***Bottom:*** **Rotor (left) and stator (right) used in the generator. These parts are economically made by printed circuit techniques using copper foil laminated phenolic selectively etched to produce the patterns.**

adopted because it is the most reliable and because the polarizing potential is already available in the associated electronic equipment.

Experiments indicate that size places no particular limitation on the successful performance of the printed-circuit generators. Practical units as small as 1⅝ inch in diameter have been constructed. As the size decreases, however, the output current decreases correspondingly; the disadvantage here is that a longer time is required to charge the storage capacitor. The spacing of the elements having maximum potential stress determines the output voltage.

Experience with the NBS electrostatic generator shows that a 0.02-microfarad capacitor can be charged to two kilovolts in about 15 seconds. In use in the radiation survey instrument, the capacitor needs to be recharged only occasionally to make up a leakage loss of about 100 volts. This can be replenished by the generator in a single operation of the lever on the driving mechanism.

symposium on high-temperature organic and semiorganic materials

BASIC PROBLEMS arising in the investigation of high-temperature liquids and polymers were discussed in a symposium held at the National Bureau of Standards in Washington, D. C., on November 2 and 3, 1953. A total of 28 technical papers were presented before approximately 250 scientists representing industrial, government, and university laboratories. Chairman of the meeting was C. W. Beckett, chief of the NBS thermodynamics laboratory.

In recent years, there has been increasing scientific interest in substances that are stable at high temperatures and that also have a wide variety of other useful properties. One class of high-temperature materials that is becoming rather well defined is that of the organic or semiorganic liquids and polymers. The physical properties of these substances are the result of inter- and intramolecular forces which are associated with strong covalent bonds in a chainlike molecule having weak forces between chains. In most cases the chain may also have many geometric configurations because of the relatively free rotation of parts of the molecule about axes provided by the chain linkages. In these characteristics and in their stability at temperatures between 250° and 500° C., the high-temperature liquids and polymers differ markedly from most of the better known materials such as rubber and ceramics.

The symposium was held to permit exchange of information between the various groups working in the field and to stimulate research in fields pertinent to high-temperature materials. The program was divided into three sessions: Kinetics and Mechanism of Thermal Decomposition, Structure and Physical Properties, and Synthesis. Some of the important questions discussed at the meeting were as follows:

(1) What chemical elements or groups are likely to contribute significantly to the thermal stability of molecules of this class?

(2) What properties may be expected from various combinations of these structural units?

(3) How can such materials be obtained, and how can their properties be determined?

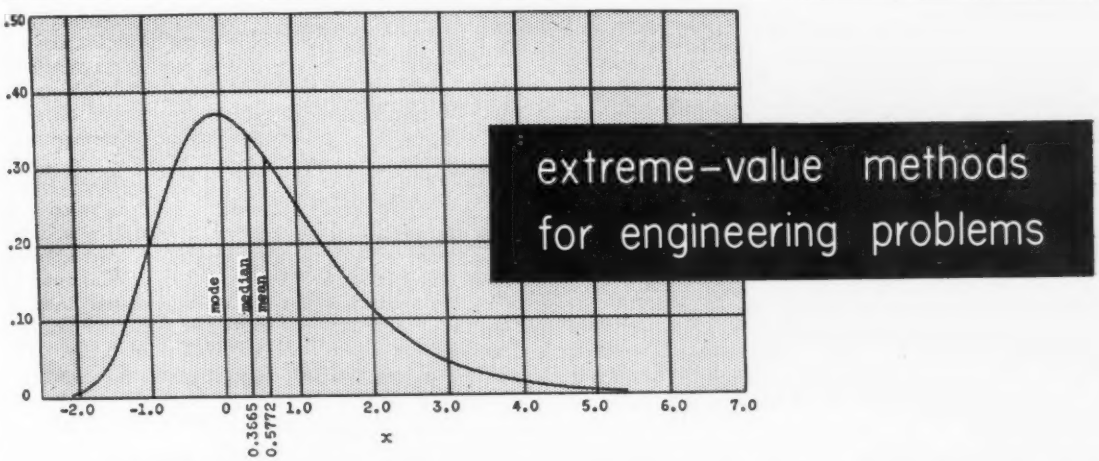
The first question was discussed from many viewpoints throughout the meeting. For example, during the first session papers dealing with the kinetics and mechanism of thermal decomposition were presented by F. O. Rice (Catholic University of America), L. A. Wall (NBS), S. L. Madorsky (NBS), R. L. Loftness (North American Aviation), and M. Szwarc (Syracuse University). Several of the lectures and discussions in the subsequent sessions were also relevant to this question.

The session on structure and properties included some discussion of the second question. Particularly pertinent was a paper presented by F. R. Eirich (Polytechnic Institute of Brooklyn) on the conditions to be satisfied for the preparation of heat- and abrasion-resistant clear resins. A series of short papers by members of the NBS staff described briefly current experimental and theoretical research at the Bureau on thermodynamic, electrical, mechanical, and molecular properties. This group of papers began with an introductory discussion led by C. W. Beckett on molecular structure and thermal stability. NBS research on the

optical and mass spectra of various fluorine compounds was then summarized by A. J. Bilbo and G. Wyman, D. E. Mann, and V. H. Dibeler. Recent thermodynamic measurements at the Bureau on Teflon and related fluorine compounds were reported by G. T. Furukawa, C. E. Weir, and R. S. Jessup. NBS research on methods of measuring several physical properties in the high-temperature range were also presented by D. C. Ginnings and E. D. West (thermal conductivity and specific heat); A. H. Scott, R. C. Powell, and G. Birnbaum (dielectric properties); P. Bradt and F. L. Mohler (mass spectra of nonvolative materials); and P. Goodman and A. B. Bestul (mechanical degradation).

The session on synthesis consisted of somewhat longer papers on several classes of materials which are promising from the thermal stability viewpoint. Two papers on aromatic hydrocarbons were presented by G. A. Edwards, K. C. Jackson, and W. G. Wright (Tuskegee Institute); and by R. L. Alexander and T. W. Mears (NBS). Three papers on aryl silanes were given by L. Spialter, D. C. Priest, and C. W. Harris (Wright Air Development Center); by L. A. Wall (NBS); and by M. Maienthal and C. Haber (Diamond Ordnance Fuze Laboratory). The synthesis of aromatic polymers containing phosphorus and nitrogen was treated by C. Haber (Naval Ordnance Laboratory, Corona, Calif.), and the thermal stability and effect of additives on modified phenolic resins were discussed by J. Littlefield and William Mecum (both of American Brake Shoe Company) and A. A. Morton (MIT). Three papers on the synthesis of fluorocarbons were presented by M. Hellman (NBS), R. Corley (Polaroid Corporation), and R. E. Florin (NBS).

Research reported at the meeting would seem to indicate that partially or completely conjugated chains of alternating single and double or triple bonds are most likely to fulfill requirements for liquids or polymers stable at temperatures from about 400 to 500° C. Elements forming the chain may be carbon, silicon, nitrogen, or phosphorus, and perhaps a few others. Of the aliphatic or single-bond structures, only the fluorocarbons appear to be in this higher-temperature class. Although these conclusions represent the concensus of current opinion as brought out in the discussions, there was sufficient divergence of viewpoint to emphasize the need for basic research of an even broader scope in the field of high-temperature materials.

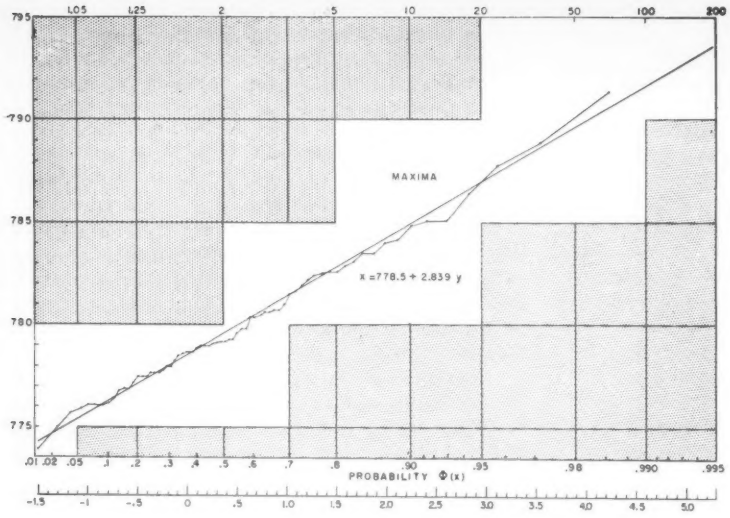


extreme-value methods for engineering problems

NEW STATISTICAL METHODS for evaluating research and development programs at NBS are fast becoming as much a part of the experimental procedure as other forms of applied mathematics. One program, originally sponsored by the National Advisory Committee on Aeronautics, is concerned with the effects of maximum gust velocities on aircraft structures. The Bureau has been concerned with the mathematical treatment of extreme values and the utilization of these and other data as a means of predicting future performance.

Extreme-value techniques are also applicable in the study of floods and droughts, which are defined as the largest and smallest daily discharges of a stream during a year. A forecast of floods is necessary for the construction of channels, bridges, reservoirs, dams, and hydroelectric plants. The study of droughts is of essential value in treating problems arising from stream pollution, sewage disposal, and water supply. Still another example occurs in the fracturing of metals, textiles, and other materials under applied force. In these instances, the observed strength of a specimen often differs from the calculated strength, and depends, among other things, upon the length and volume. The explanation is to be found in the existence of weakening flaws assumed to be distributed at random in the body and assumed not to influence one another in any way. The observed strength is determined by the weakest region. A similar "smallest value" approach may

Top left: **Distribution of data in which largest extreme values are involved. Unlike the normal distribution of data, the extreme-value curve is skewed—rising to a maximum to one side of the mean. Thus larger values have a decidedly greater chance of occurring than correspondingly small values.**



Annual maxima of atmospheric pressures at Bergen, Norway, 1857–1926. These data are plotted on extreme-value probability paper, in which the ordinate is ruled with equal spacing and the abscissa is marked according to a straight line. The closeness of the plotted points to this straight line is an indication of how well the data fit the theory. From this curve, for example, it is possible to predict that a pressure of 793 mm has less than 1 chance in 100 of being exceeded.

be applied to the study of voltage breakdown in electrical capacitors.

Meteorological phenomena that involve extreme pressures, temperatures, rainfalls, wind velocities, or other similar items may also be treated by extreme-value techniques. These data have important application to revisions of the National Electrical Safety Code, which require that the design specifications of power line supports take into consideration wind pressures as compiled by the U. S. Weather Bureau. Similar specifications have also been included in certain building codes. Such requirements create a problem in predicting the likelihood of the occurrence of extreme wind pressures or velocities from observed data. Common statistical procedure is based on the assumption that observations often follow the normal or bell-shaped frequency curve which is symmetrical about the average. However, certain phenomena are distributed in a markedly unsymmetrical manner. In other words, the largest extremes always tend to push toward the higher values rather than the lower ones; whereas in the case of a normal distribution, the tendencies toward high and low values are equal.

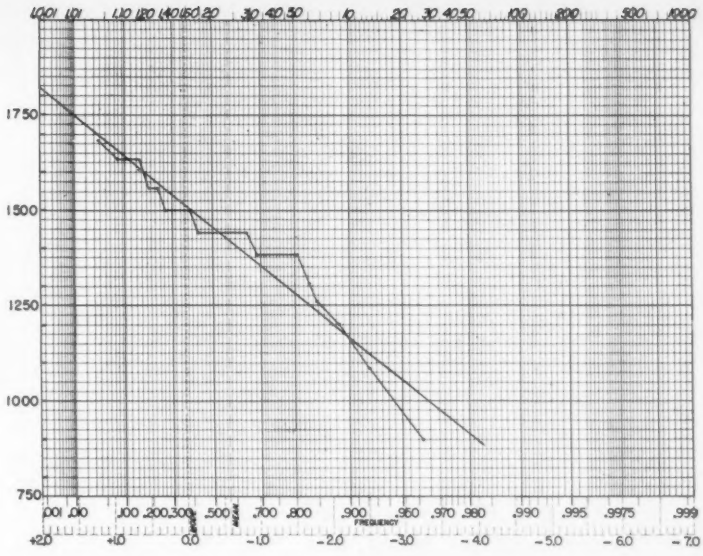
In view of this fact, the symmetrical normal distribution curve will not supply the information required to predict extreme conditions. However, if the curve is skewed—rising to a maximum to one side of the mean—the larger values have a decidedly greater chance of happening than the very small values. Theoretical considerations leading to a curve of this nature, called the distribution of largest values or the extreme-value distribution, were first studied by Fisher and Tippett,[1] and in recent years the theory has been successfully applied to many engineering problems by E. J. Gumbel.[2]

In using the extreme-value method all the observed maxima, such as the largest wind velocity observed in each year during a fifty-year period, are first ranked in order of size from the smallest to the largest. These values are given ranks 1 to n and are then transformed into probability numbers by the relation $P_i = i/(n+1)$, where i is the rank of the ith observation counting from the smallest. Thus a probability value is obtained for each observation. The data are plotted on a special graph paper, called extreme-value probability paper, designed so that the "ideal" extreme-value distribution will plot exactly as a straight line. Consequently, the closeness of the plotted points to a straight line is an indication of how well the data fit the theory.

Extreme-value probability paper is often ruled with equal spacing along the ordinate or vertical axis, along which the observed values are measured. The abscissa or horizontal axis, which serves as the probability scale, is marked according to a doubly exponential formula. Thus the spacing between 0.001 and 0.500 is much less than half the space between 0.500 and 0.999. The limiting values 0 and 1 are never reached.

An extreme-value plot of the maximum atmospheric pressures in Bergen, Norway, for the period between 1857 and 1926 showed that the observed data satisfactorily fitted the theory. From the curve it is possible to predict, for example, that a pressure of 793 mm corresponds to a probability of 0.993, that is, pressures of this magnitude have less than 1 chance in 100 of being exceeded. In studies of the normal acceleration increments experienced by an airplane flying through gusty air, an instrument was employed that indicated only the maximum shocks. Thus, only one observation was obtained from a single flight. A plot representing 26 flights of the same aircraft indicated that the probability of the most violent gust not to be exceeded in any other flight was 0.955, which is equivalent to a chance of less than 5 in 100 of encountering a *more* severe gust than any recorded.

Extreme-value theory can also be used to study the smallest extremes. Here, the steps in applying the "smallest-values" theory are very similar to the largest-values case. For example, engineers have long been



Breakdown voltage of capacitors. This is an example of "smallest-value" phenomena in which the extreme-value techniques are still applicable. This plot of 25 paper capacitors shows that there are 96 chances out of 100 that the capacitor will fail if voltages up to 1,700 are applied. However, if this maximum voltage is held to 900 there are but 2 chances in 100 that the capacitor will fail. These "smallest-value" data are plotted on the extreme-value probability paper and tend to approximate a downward-sloping line.

interested in the problems of predicting the tensile strength of a bar of homogeneous material. One approach is to regard the specimen as being composed of a great number of smaller pieces of very short length. The tensile strength of the entire specimen is obviously limited by the strength of the weakest of these small pieces. Thus the tensile strength at which the entire specimen will fail is a smallest-value phenomenon. The smallest-values theory can be applied even though the number and individual strengths of the "small pieces" are unknown; it is only necessary to assume that these strengths have a certain general type of statistical distribution.

Another application of smallest extreme values is in studying the breakdown voltage of electrical capacitors. The theory on which the statistical analysis is based is that every capacitor contains flaws that are conducting particles. The capacitor breaks down at the voltage which is passed by the weakest particle. This is a typical smallest-value phenomenon. A plot of the experimental data from a group of 25 paper capacitors indicates that there are 96 chances out of 100 that the capacitors will fail if voltages up to 1,700 are applied. However, if this maximum voltage is held to 900, there are but 2 chances in 100 that the capacitors will fail.

Extreme-value theory was first extensively applied to the problem of floods. The yearly maxima of all the 365 daily flows of the Tennessee and Cumberland Rivers were recorded for periods of about 60 and 90 years, respectively. These maxima are plotted on extreme-value probability paper, from which can be read the probability that a flood of any given magnitude will be exceeded in a single year. The information is useful for classifying streams and rivers in several statewide areas, which permits their orderly study and serves as a rough guide for planning purposes.

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[1] *R. A. Fisher and L. H. C. Tippett*, Limiting forms of the frequency distribution of the largest or smallest member of a sample. *Proc. Cambridge Phil. Soc.* **24**, *Pt. 2, 180–190 (1928)*.

[2] The statistical theory of extreme values and some practical applications, *by E. J. Gumbel, National Bureau of Standards Applied Mathematics Series 33 (AMS 33). (In press.)*

For further technical information on extreme-value techniques, see Probability tables for the analysis of extreme-value data, National Bureau of Standards Applied Mathematics Series 22 (*available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., Price: 25 cents*); A new method of analyzing extreme-value data, *by Julius Lieblein, NACA Technical Note, 3053 (in press)*.

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RP2464. Apparatus for the determination of minor components of a gas mixture. Martin Shepherd.

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SINCLAIR WEEKS, *Secretary*
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A. V. ASTIN, *Director*

February 1954 Issued Monthly Vol. 38, No. 2

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